ISTRY OF AGRICULTURE, FISHERIES AND FOOD

SHERY INVESTIGATIONS
es II, Volume 27, Number 8

ne Yorkshire fishery for dible crabs *(Cancer pagurus)*: ssessment of the effects changes in ne minimum legal size

A. HANCOCK*

ries Laboratory, Burnham-on-Crouch, Essex

ent address: Department of Fisheries and Wildlife,
ne Research Laboratories, Waterman, Perth, Western Australia

NDON:
R MAJESTY'S STATIONERY OFFICE

© *Crown copyright 1975*
First published 1975

ISBN 0 11 241088 X

MINISTRY OF AGRICULTURE, FISHERIES AND FOOD

Fishery Investigations, Series II, Volume 27, Number 8

"The Yorkshire fishery for edible crabs (Cancer pagurus): Assessment of the effects of changes in the minimum legal size" by D. A. Hancock

ERRATA

Page 2, column 1, line 6 to line 23 should read:

Percentage loss in numbers (x) $= 100(C_1 - C_2)/C_1$

$= 100\left[C_1 - \left\{E.N_R.\exp(-Mt') + N_K\right\}\right]/C_1$

$= 100 - \left\{E.\exp(-Mt')\right\}.(100N_R/C_1) - 100\,N_K/C_1$

$= 100\left\{1 - E.\exp(-Mt')\right\}.N_R/C_1$

Percentage change in weight $= 100(Y_2 - Y_1)/Y_1$

$= 100(C_2\overline{W}_2 - C_1\overline{W}_1)/C_1\overline{W}_1$

$= (100 - x)(\overline{W}_2/\overline{W}_1) - 100$ ..... (1)

Substituting for $\overline{W}_2$, and using $\dot{N}_K$, $\dot{N}_R$ and $\dot{C}_2$ to represent N_K, N_R and C_2 expressed as percentages of C_1,

Percentage change in weight =

$\left[\left\{(100 - x)/\overline{W}_1\right\}.\left\{\dot{N}_K.\overline{W}_K + E.\dot{N}_R.\exp(-Mt').\overline{W}_R\right\}/\dot{C}_2\right] - 100$

Which since $\dot{C}_2 = 100 - x$, reduces to

$\left[\left\{\dot{N}_K.\overline{W}_K + E.\dot{N}_R.\exp(-Mt').\overline{W}_R\right\}/\overline{W}_1\right] - 100$

and since $\dot{N}_R.E.\exp(-Mt') = 100 - x - \dot{N}_K$

this further reduces to

$(100 - x)(\overline{W}_R/\overline{W}_1) - 100 - \dot{N}_K(\overline{W}_R - \overline{W}_K)/\overline{W}_1$ ..... (2)

ontents

TRACT . . . . . *Page* iv

RODUCTION 1

THOD 1

PARATION OF TABULATED DATA 2

OF TABULATED DATA 4

CTICAL ADVANTAGES OF TABULATED DATA 5

LD ASSESSMENT IN THE YORKSHIRE FISHERY 6

ULTS OF THE ASSESSMENT 7

IABILITY OF PARAMETERS USED IN THE ASSESSMENT 9

MARY AND CONCLUSIONS 11

ERENCES 11

Abstract

In an earlier paper (Hancock, 1965) the method of Gulland (1961) was used to examine the effects on yield of increasing the minimum legal size in the Norfolk crab fishery. When applying the technique to the Yorkshire crab fishery certain modifications were found to be necessary. Tabulated display of the results obtained from considering a wide range of values for the variables employed has the practical advantage of allowing inspection to determine which parameters are of significance to the end result. It was concluded that in the Yorkshire crab fishery no reliable increase in long-term weight yields would be likely to accrue from an increase in minimum size from $4\frac{1}{2}$ to 5 inches.

ntroduction

Edwards (1967, and in prep.) has described the edible crab ery of Yorkshire and the making of observations needed assessing and predicting the effects of possible changes he present minimum legal size of 4½ inches (11.4 cm). In earlier paper (Hancock, 1965) the method of Gulland 61) was used to examine the effects on yield of increasing minimum size in the Norfolk crab fishery. The subsent application of this method to the Yorkshire fishery de clear the need for reducing the amount of cumbersome nputation involved. Computer analysis has provided the ans for rapid evaluation of combinations of values for the ameters involved in the calculations; however tabulated play of the results has given a practical method for recogng the direction and magnitude of changes in yield reing from employing different values for the tain modifications were found to be required in the culation so as to cover fully the assessment of changes in weight of landings which would result from different imum sizes, and this has involved a revision of the final ge of the Norfolk assessment presented in 1965. The clusions of the Yorkshire assessment were presented in a liminary report (Edwards, 1967); the present account is nded to give more details of the information and methused in reaching those conclusions.

Method

The expected percentage reduction in numbers and pertage change in weight of catch resulting from an increase he minimum legal size can be calculated from:

$$C_2 = N_K + E.N_R.e^{-Mt'}$$ (Hancock, 1965 after Gulland, 1961)

re C_2=expected catch in numbers in the steady state g the new minimum size $^lc_2$,

N_K=immediate catch in number of crabs larger than $^lc_2$,

E=expectation of death by capture,

N_R=number of crabs released in the size range $^lc_1$ to $^lc_2$,

M=instantaneous natural mortality coefficient,

t′=average time for crabs to grow from $^lc_1$ to $^lc_2$.

the assessment of the Norfolk crab fishery the calculation based on annual catches taken during a fishing season fined to 6 months of each year.)

he basis for this relationship, in simple terms, is that in present catch, obtained with minimum size $^lc_1$, the total nber of crabs landed (C_1)=N_R+N_K, of which N_K crabs larger than the newly chosen minimum size $^lc_2$, and N_R n the size range between $^lc_1$ and $^lc_2$ (Figure 1). Immediy following the increase in minimum size to $^lc_2$ the catch be composed only of N_K crabs and these, unless other ors change, will make a permanent annual contribution he catch when equilibrium has been reached. As growth eeds, to N_K will be added some of the survivors of N_R. The number of these which will be caught will depend on the rate of fishing, the rate of death from natural causes and the time before they reach the new legal size, and is equal to $E.N_R.\exp(-Mt')$. In this, $\exp(-Mt')$ governs the proportion of N_R which survives to the new minimum size by taking account of the numbers which die due to natural mortality (M) during the average time (t′) taken for them to grow to $^lc_2$. The number of survivors of N_R to $^lc_2$ which will be subsequently caught depends on the relative strengths of F* and M; these are taken into account in the value of E, which expresses the chance of capture of the survivors of N_R throughout the rest of their lives. E is here represented as the ratio of the number caught by fishing (C) to the number which die from all causes (C+D), where D=the number dying from natural causes; i.e., E=C/(C+D). The resultant catch in numbers in the steady state (C_2) is therefore equal to the sum of N_K, plus N_R reduced by $\exp(-Mt')$ and by E;

i.e. $C_2 = N_K + E.N_R.\exp(-Mt')$.

C_2 will therefore always be less than C_1, the original catch in numbers. Despite this loss in numbers there may still be an eventual gain in weight in the steady state, depending on the ratio of the average weights before and after the change. The new yield in weight (Y_2) of crabs larger than $^lc_2$ will be equal to the numbers in the catch (C_2) multiplied by the mean weight ($\bar{W}_2$) of crabs larger than $^lc_2$ in the steady state, and may be compared with the weight of the catch (Y_1) obtained using $^lc_1$.

In the previous paper (Hancock, 1965), $\bar{W}_2$ was taken to equal the mean weight of crabs larger than $^lc_2$ in the present catch. It seems clear, however, after subsequent discussion with Dr. Gulland, that the model presented there, although it describes the special case in which the proposed increase in minimum size ($^lc_1$ to $^lc_2$) exactly equals one moult increment, is not fully representative when the moult increment is greater or less than the difference between $^lc_1$ and $^lc_2$. In edible crabs, the moult increment of a 4½ inch† crab, at about 1 inch (Edwards, 1965; Hancock and Edwards, 1967) exceeds the increases in minimum size (4½ inches to 4¾ or 5 inches) which were under consideration for Norfolk. Crabs (N_R) in the release range ($^lc_1$ to $^lc_2$) would therefore be, after moulting, quite a bit bigger than the smallest crabs in the kept catch (N_K). $\bar{W}_R$, the average weight of N_R crabs when caught after the system has reached equilibrium, would therefore be greater than $\bar{W}_K$, the average weight in the kept catch (N_K), and thus the value of $\bar{W}_2$ would also be greater than $\bar{W}_K$ (Figure 1). In consequence, the values given for percentage changes in weight by Hancock (1965, Table 6) will have been underestimated. The value of $\bar{W}_2$, the average weight of crabs larger than $^lc_2$ in the steady state, by which the new catch in numbers (C_2) should be multiplied to give the new yield (Y_2), should in fact be calculated from:

$$\bar{W}_2 = \left\{ N_K.\bar{W}_K + E.N_R.\exp(-Mt').\bar{W}_R \right\} / \left\{ N_K + E.N_R.\exp(-Mt') \right\}$$

where $N_K + E.N_R.\exp(-Mt')$ also $= C_2$.

* F is the instantaneous fishing mortality coefficient; F+M=Z, the instantaneous total mortality co-efficient.

† 1 inch=25.4 mm.

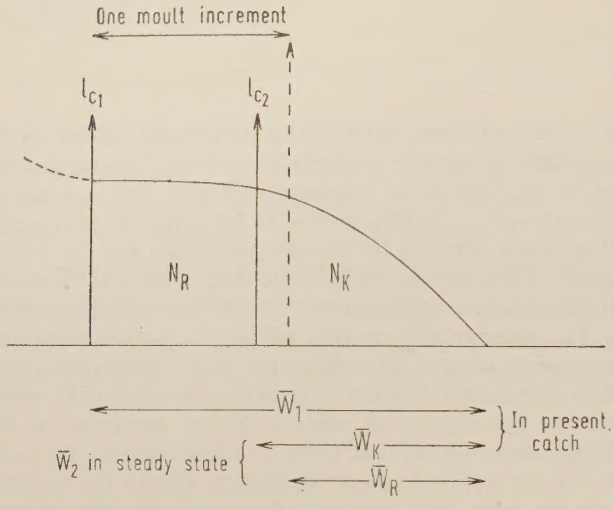

Fig. 1. Diagrammatic representation of the size composition of landed crabs, showing the relationship of the various numerical components (N_K and N_R) and average weights $\bar{W}_1$, $\bar{W}_K$, $\bar{W}_R$ and $\bar{W}_2$ with changes in the minimum size, and with moult increment.

The calculations employing values for the actual numbers and weight of crabs in the annual catch (Hancock, 1965) were very laborious. Reconsideration of the method showed that the arithmetic could be simplified by using N_R expressed as a percentage of the total original catch (C_1), as follows:

Percentage loss in numbers (x) $= 100(C_1 - C_2)/C_1$

$$= 100\left[C_1 - \left\{E.N_R.\exp(-Mt') + N_K\right\}\right]/C_1$$

$$= 100 - \left\{E.\exp(-Mt')\right\}.(100N_R/C_1) - 100\ N_K/C_1)$$

$$= 100 - \left\{1 - E.\exp(-Mt')\right\}.N_R/C_1$$

Percentage change in weight $= 100Y_2 - Y)/Y_1$

$$= 100(C_2\bar{W}_2 - C_1\bar{W}_1)/C_1\bar{W}_1$$

$$= (100 - x)(\bar{W}_R/\bar{W}_1) - 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Substituting for $\bar{W}_2$, and using $\dot{N}_K$, $\dot{N}_R$ and $\dot{C}_2$ to represent N_K, N_R and $\dot{C}_2$ expressed as percentages of C_1,

Percentage change in weight $=$

$$\left[\left\{(100 - x)/\bar{W}_1\right\}.\left\{\dot{N}_K.\bar{W}_K + E.\dot{N}_R.\exp(-Mt').\bar{W}_R\right\} / C_2.\right] - 100$$

Which since $\dot{C}_2 = 100 - x$, reduces to

$$\left[\left\{(\dot{N}_K.\bar{W}_K + E.\dot{N}_R.\exp(-Mt').\bar{W}_R\right\}/\bar{W}_1\right] - 100$$

and since $\dot{N}_R.E.\exp(-Mt') = 100 - x - \dot{N}_K$ this further reduces to

$$(100 - x)(\bar{W}_R/\bar{W}_1) - 100 - \dot{N}_K(\bar{W}_R - \bar{W}_K)/\bar{W}_1 \quad \ldots\ldots\ldots (2)$$

which is of the same form as (1) above, with an extra subtracted term. Expression (1) can be used in the special case where the moult increment exactly equals the increase in minimum size from l_{c_1} to l_{c_2}, when $\bar{W}_2 = \bar{W}_R = \bar{W}_K$. Expression (2) is appropriate when the moult increment is larger than the minimum size increase. Conversion of the equation into this form has allowed the preparation of readily referable tables as shown in the following sections.

Preparation of Tabulated Data

Using the simplified calculation above, the results tained from substituting a wide range of possible value the parameters of the assessment equation have been t lated.

In Table 1, values of F, M and t′ have been combine give values of the quotient E.exp(−Mt′). For the fisheries of Norfolk and Yorkshire, where fishing place only during 6 months of the year,

$$E = F\left[1 - \exp\left\{-0{\cdot}5(F+M)\right\}\right] / \left[(F+M)\left\{1 - \exp(-0.5F+M)\right\}\right]$$

(Hancock, 1965) and this expression has been used to c late values of E in Table 1. For a fishery operating thro out the year, calculation of E would be simplified since $E = F/(F+M)$ (Gulland, 1961), and Table 1 could be e retabulated by combining the new values of E with tho exp(−Mt′) given in Table 1. From Table 1 it is then pos to select a set of likely parameters for the fishery under sideration, or to examine a whole range of possible co nations.

In Table 2, values of E.exp(−Mt′) (rounded to 2 dec places) have been tabulated against whole values of $\dot{N}_R$ percentage loss in numbers in the first year after chan the minimum size. The tabulated result gives the percen loss in numbers (x), expected in the steady state, calcul from $(100N_R/C_1)\left\{1 - E.\exp(-Mt')\right\}$

In Table 3, values of the ratio $\bar{W}_R/\bar{W}_1$ (to 2 dec places), and of x, have been used to tabulate values fo expression $(100 - x).(\bar{W}_R/\bar{W}_1) - 100$. This table can be directly to predict the change in weight in the steady sta the special case where moult increment equals minimum increase, i.e. $\bar{W}_R = \bar{W}_2$. In the present situation, where proposed increase in size limit is less than one moult i ment, the result obtained from Table 3 requires the traction of the value of $\dot{N}_K(\bar{W}_R - \bar{W}_K)/\bar{W}_1$ which is calcu (as y) quite simply, as shown in the worked example data from the Norfolk fishery (Hancock, 1965) give Table 4, and discussed in the following section.

Actual values of numbers lost or changes in weight when required, be easily obtained by relating the percen values to the total present catch C_1 and Y_1. Due to roun of the values used in the tables, the degree of accuracy o result will be slightly reduced, but using the tables it wi possible to make a quick initial assessment which ca followed by detailed calculations using more precise v of selected parameters, should this be required. Simil Table 1 does not attempt to include every combinatio F, M and t′, but gives a range of possibilities from whi select values for more precise computation. For brevity specimen tables are given in Tables 2 and 3, but more prehensive tables using values of 0.01 to 0.99 for E (-Mt′), 1 to 99 for x, and 1.01 to 2.00 for $\bar{W}_R/\bar{W}_1$, prod using an Elliott 803 computer, have been used in actua culations.

TABLE 1 *Calculation of E.exp(−Mt′) for various values of F, M and t′ based on fishing during six months*

Annual F	*%Loss in 6 months from fishing	Annual M	†Annual % natural loss	Effective % loss due to F	Effective % loss due to M	E	t′‡	exp(−Mt′)	E.exp(−Mt′)	t′‡	exp(−Mt′)	E.exp(−Mt′)	t′‡	exp(−Mt′)	E.exp(−Mt′)
0.44	20	0.11	10	19	9	0.69	1	0.90	0.62	1.2	0.88	0.61	1.50	0.86	0.59
0.72	30	0.11	10	29	8	0.79	1	0.90	0.71	1.2	0.88	0.70	1.50	0.86	0.68
1.02	40	0.11	10	39	7	0.85	1	0.90	0.77	1.2	0.88	0.75	1.50	0.86	0.73
1.38	50	0.11	10	49	6	0.89	1	0.90	0.80	1.2	0.88	0.78	1.50	0.86	0.77
1.84	60	0.11	10	59	5	0.92	1	0.90	0.83	1.2	0.88	0.81	1.50	0.86	0.79
2.40	70	0.11	10	68	5	0.94	1	0.90	0.85	1.2	0.88	0.83	1.50	0.86	0.81
3.22	80	0.11	10	78	4	0.96	1	0.90	0.86	1.2	0.88	0.84	1.50	0.86	0.83
4.60	90	0.11	10	89	2	0.97	1	0.90	0.87	1.2	0.88	0.85	1.50	0.86	0.83
0.44	20	0.22	20	19	17	0.53	1	0.80	0.42	1.2	0.77	0.41	1.45	0.73	0.39
0.72	30	0.22	20	28	16	0.65	1	0.80	0.52	1.2	0.77	0.50	1.45	0.73	0.47
1.02	40	0.22	20	38	14	0.73	1	0.80	0.58	1.2	0.77	0.56	1.45	0.73	0.53
1.38	50	0.22	20	47	13	0.80	1	0.80	0.64	1.2	0.77	0.62	1.45	0.73	0.58
1.84	60	0.22	20	57	11	0.84	1	0.80	0.67	1.2	0.77	0.65	1.45	0.73	0.61
2.40	70	0.22	20	67	9	0.88	1	0.80	0.70	1.2	0.77	0.68	1.45	0.73	0.64
3.22	80	0.22	20	77	7	0.91	1	0.80	0.73	1.2	0.77	0.70	1.45	0.73	0.66
4.60	90	0.22	20	87	5	0.95	1	0.80	0.76	1.2	0.77	0.73	1.45	0.73	0.69
0.44	20	0.36	30	18	26	0.41	1	0.70	0.29	1.2	0.65	0.27	1.44	0.59	0.24
0.72	30	0.36	30	28	23	0.54	1	0.70	0.38	1.2	0.65	0.35	1.44	0.59	0.32
1.02	40	0.36	30	37	21	0.63	1	0.70	0.44	1.2	0.65	0.41	1.44	0.59	0.37
1.38	50	0.36	30	46	19	0.71	1	0.70	0.50	1.2	0.65	0.46	1.44	0.59	0.42
1.84	60	0.36	30	54	18	0.77	1	0.70	0.54	1.2	0.65	0.50	1.44	0.59	0.45
2.40	70	0.36	30	65	14	0.82	1	0.70	0.57	1.2	0.65	0.53	1.44	0.59	0.48
3.22	80	0.36	30	75	11	0.87	1	0.70	0.61	1.2	0.65	0.57	1.44	0.59	0.51
4.60	90	0.36	30	85	8	0.91	1	0.70	0.64	1.2	0.65	0.59	1.44	0.59	0.54
0.44	20	0.69	50	17	43	0.28	1	0.50	0.14	1.2	0.43	0.12	1.41	0.38	0.11
0.72	30	0.69	50	26	39	0.40	1	0.50	0.20	1.2	0.43	0.17	1.41	0.38	0.15
1.02	40	0.69	50	34	36	0.49	1	0.50	0.25	1.2	0.43	0.21	1.41	0.38	0.19
1.38	50	0.69	50	43	32	0.58	1	0.50	0.29	1.2	0.43	0.25	1.41	0.38	0.22
1.84	60	0.69	50	52	28	0.65	1	0.50	0.33	1.2	0.43	0.28	1.41	0.38	0.25
2.40	70	0.69	50	61	24	0.72	1	0.50	0.36	1.2	0.43	0.31	1.41	0.38	0.27
3.22	80	0.69	50	71	19	0.79	1	0.50	0.40	1.2	0.43	0.34	1.41	0.38	0.30
4.60	90	0.69	50	81	14	0.85	1	0.50	0.43	1.2	0.43	0.37	1.41	0.38	0.32

* In absence of natural mortality.
† In absence of fishing mortality.
‡ With t′=1, all crabs released moult once each year.
With t′=1.2, 75% moult in the first year, and most of the remainder in the following year.
t′=1.50→1.41 represent 50% moulting in the first year, followed by most of the remainder in the next year, corresponding to M=0.11→0.69 (see Hancock, 1965).

TABLE 2 *Annual percentage losses in numbers (x) in the steady state, calculated from* $\dot{N}_R\left\{(1-E.exp(-Mt')\right\}$, *where is a percentage of the total catch* C_1

E.exp(−Mt′)	Values of $\dot{N}_R$																	
	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	9
0.05	5	10	14	19	24	29	33	38	43	48	52	57	62	67	71	76	81	8
0.10	5	9	14	18	23	27	32	36	41	45	50	54	59	63	68	72	77	8
0.15	4	9	13	17	21	26	30	34	38	43	47	51	55	60	64	68	72	7
0.20	4	8	12	16	20	24	28	32	36	40	44	48	52	56	60	64	68	7
0.25	4	8	11	15	19	23	26	30	34	38	41	45	49	53	56	60	64	6
0.30	4	7	11	14	18	21	25	28	32	35	39	42	46	49	53	56	60	6
0.35	3	7	10	13	16	20	23	26	29	33	36	39	42	46	49	52	55	5
0.40	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48	51	5
0.45	3	6	8	11	14	17	19	22	25	28	30	33	36	39	41	44	47	5
0.50	3	5	8	10	13	15	18	20	23	25	28	30	33	35	38	40	43	4
0.55	2	5	7	9	11	14	16	18	20	23	25	27	29	32	34	36	38	4
0.60	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	3
0.65	2	4	5	7	9	11	12	14	16	18	19	21	23	25	26	28	30	3
0.70	2	3	5	6	8	9	11	12	14	15	17	18	20	21	23	24	26	2
0.75	1	3	4	5	6	8	9	10	11	13	14	15	16	18	19	20	21	2
0.80	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	1
0.85	1	2	2	3	4	5	5	6	7	8	8	9	10	11	11	12	13	1
0.90	1	1	2	2	3	3	4	4	5	5	6	6	7	7	8	8	9	
0.95	0	1	1	1	1	2	2	2	2	3	3	3	3	3	4	4	4	

TABLE 3 *Calculation of the function* $(100-x)(\bar{W}_R/\bar{W}_1)-100$, *where x=percentage loss in numbers (Table 2) and* $\bar{W}_R$ *and are the mean weights of selected fractions of the catch*

x	$\bar{W}_R/\bar{W}_1$																			
	1.05	1.10	1.15	1.20	1.25	1.30	1.35	1.40	1.45	1.50	1.55	1.60	1.65	1.70	1.75	1.80	1.85	1.90	1.95	2
1	+4	+9	14	19	24	29	34	39	44	49	53	58	63	68	73	78	83	88	93	
5	0	+5	9	14	19	24	28	33	38	43	47	52	57	62	66	71	76	81	85	
10	−5	−1	4	8	13	17	22	26	31	35	40	44	49	53	58	62	67	71	76	
15	−11	−6	−2	2	6	11	15	19	23	28	32	36	40	45	49	53	57	62	66	
20	−16	−12	−8	−4	0	4	8	12	16	20	24	28	32	36	40	44	48	52	56	
25	−21	−17	−14	−10	−6	−2	1	5	9	13	16	20	24	28	31	35	39	43	46	
30	−26	−23	−19	−16	−12	−9	−5	−2	2	5	9	12	16	19	23	26	30	33	37	
35	−32	−28	−25	−22	−19	−15	−12	−9	−6	−2	1	4	7	11	14	17	20	24	27	
40	−37	−34	−31	−28	−25	−22	−19	−16	−13	−10	−7	−4	−1	2	5	8	11	14	17	
45	−42	−39	−37	−34	−31	−28	−26	−23	−20	−17	−15	−12	−9	−6	−4	−1	2	5	7	
50	−47	−45	−42	−40	−37	−35	−32	−30	−27	−25	−22	−20	−17	−15	−12	−10	−7	−5	−2	
55	−53	−50	−48	−46	−44	−41	−39	−37	−35	−32	−30	−28	−26	−23	−21	−19	−17	−14	−12	
60	−58	−56	−54	−52	−50	−48	−46	−44	−42	−40	−38	−36	−34	−32	−30	−28	−26	−24	−22	
65	−63	−61	−60	−58	−56	−54	−53	−51	−49	−47	−46	−44	−42	−40	−39	−37	−35	−33	−32	
70	−68	−67	−65	−64	−62	−61	−59	−58	−56	−55	−53	−52	−50	−49	−47	−46	−44	−43	−41	
75	−74	−72	−71	−70	−69	−67	−66	−65	−64	−62	−61	−60	−59	−57	−56	−55	−54	−52	−51	
80	−79	−78	−77	−76	−75	−74	−73	−72	−71	−70	−69	−68	−67	−66	−65	−64	−63	−62	−61	
85	−84	−83	−83	−82	−81	−80	−80	−79	−78	−77	−77	−76	−75	−74	−74	−73	−72	−71	−71	
90	−89	−89	−88	−88	−87	−87	−86	−86	−85	−85	−84	−84	−83	−83	−82	−82	−81	−81	−80	
95	−95	−94	−94	−94	−94	−93	−93	−93	−93	−92	−92	−92	−92	−91	−91	−91	−91	−90	−90	

Use of Tabulated Data

As an example of typical data necessary for an assessment of this type, the 1959 values for the Norfolk fishery given by Hancock (1965, Table 1) have been re-expressed in Table 4. Using Tables 1 to 4, the example given on page 92 of Hancock (1965) has been recalculated in Table 4. This uses the assumption, which is supported by field data from tagging experiments (Hancock and Edwards, 1967; Edwards, 1966), that the moult increment of a $4\frac{1}{2}$ inch crab on the east coast of England is approximately one inch. When the result of a minimum size increase to $4\frac{3}{4}$ inches, using total number of crabs, is compared with that shown on page 92 of Hancock (1965), although the percentage loss in numbers is unchanged, the percentage gain in weight, at 16.3%, is now, as explained earlier, a much higher figure. (This could siderably affect the previous conclusions on the advisa of making minimum size changes in the Norfolk fishery in fact other considerations, apart from an expected w increase in this fishery, mitigate against increasing the mum size.) In assessments of this type, ways of impr both the method and the estimates of values of param used are constantly being sought. It was shown by Har and Edwards (1967) that, although the moult increm approximately the same for males and females, the frequ of moulting is much less in males than in females. stresses the need for making yield assessments separate the two sexes wherever possible.

LE 4 *Assessment of the changes in yield of the Norfolk fishery which would result from minimum size increases from 4½ inches to 4¾, 5 and 5½ inches, using data from Hancock* (1965)
Annual landings were recorded in weight in stones; and therefore all weights are given in stones; 1 *stone* =6.35 *kg*

	4¾ inches			5 inches			5½ inches		
	Female	Male	Total	Female	Male	Total	Female	Male	Total
Numbers in present catch, e over 4½″ (C_1)	784 760	803 352	1 588 110	784 760	803 352	1 588 110	784 760	803 352	1 588 110
mmediate loss in numbers (N_R)	245 265	381 672	626 937	389 038	517 623	906 661	703 746	728 676	1 432 422
percentage loss=$\dot{N}_R$)	(31.2)	(47.5)	(39.5)	(49.6)	(64.4)	(57.1)	(89.7)	(90.7)	(90.2)
Weight of present catch e over 4½″ (Y_1)	41 033	43 903	84 936	41 033	43 903	84 936	41 033	43 903	84 936
mmediate loss in weight	9 623	16 012	25 635	16 250	22 926	39 176	34 290	36 553	70 843
percentage loss)	(23.4)	(36.5)	(30.2)	(39.6)	(52.2)	(46.1)	(83.6)	(83.3)	(83.4)
Mean weight of catch over 4½″ ($Y_1/C_1=\bar{W}_1$)	0.0523	0.0546	0.0535	0.0523	0.0546	0.0535	0.0523	0.0546	0.0535
Mean weight of catch over new minimum size ($\bar{W}_K$)	0.0583	0.0661	0.0617	0.0626	0.0734	0.0672	0.0832	0.0984	0.0905
Mean weight of catch over 5½″ ($\bar{W}_R$)	0.0832	0.0984	0.0905	0.0832	0.0984	0.0905	0.0832	0.0984	0.0905
$(100-\dot{N}_R).(\bar{W}_K-\bar{W}_R)/\bar{W}_1=y$	32.8	31.0	32.5	19.8	16.3	18.8	0	0	0
$\bar{W}_R/\bar{W}_1$	1.59	1.80	1.69	1.59	1.80	1.69	1.59	1.80	1.69
Rate of moulting (t′)	1	1.2	1	1	1.2	1	1	1.2	1
For M=0.22, F=2.4, from Table 1 E.exp(−Mt′)	0.70	0.68	0.70	0.70	0.68	0.70	0.70	0.68	0.70
From Table 2*, percentage loss in numbers, (x)	9.3	15.2	11.8	14.7	20.5	17.1	26.7	29.0	27.0
From Table 3 $(100-x)(\bar{W}_R/\bar{W}_1)-100$	44.7	53.0	48.8	35.2	43.1	40.3	16.1	27.8	23.4
% increase in weight, ie subtract (y) above	11.9	22.0	16.3	15.4	26.8	21.5	16.1	27.8	23.4

t using values from complete tables

n Table 4 the results are shown of using different values t′, for females (t′=1, or moulting annually) and males =1.2, or 75% moulting in the first year, and most of the nainder in the second year—Table 1). The effect on the al result can be computed by relating the percentage nges to the actual weights in the original catch:

11.9% of 41 033+22.0% of 43 903=14 541.6 stones

ich is 17.1% of the original total catch of 84 936 stones, l compares with 16.3% obtained using t′=1 for total bs. Similarly, for an increase to 5 inches, the net percent- change in weight would be 21.3% compared with 21.5% the table. Clearly, in this example the net effect of the ver moulting rate of males is very small. Table 4 also ows the result of minimum size increases to 5 and 5½ inch- and it can be seen how at 5½ inches the increase is equal to value of the moult increment, and the predicted weight nge is then fully represented in Table 3.

The main advantage of presenting the data in the form own in Table 4 is that for any selected minimum size in- ase, stages 1–7 need calculating only once and will be nstant for any particular fishery. Using Tables 1–3 a wide nge of values of the other parameters can then be em- oyed to assess the effect on the loss in numbers and the ange in weight. Previously the amount of computation nited the calculation to the use of total catch figures, but this method the results for separate sexes can be quickly examined and, equally readily, different areas from the same fishery can be compared, as will be shown for the Yorkshire fishery.

Practical Advantages of Tabulated Data

With crustacea, two of the important parameters for a yield assessment, F and t′, can be determined only from the results of tagging experiments (Hancock, 1965), which are usually time-consuming and costly. Information on the size and weight composition of the catch can, however, usually be obtained without difficulty, and data on average moult increment may also be available. By examining such data with reference to Tables 1–3, it should be possible to identify the parameter(s) having the most influence on yield changes. In certain circumstances a preliminary assessment in this way could even obviate any necessity for further experimental work, but at least it should be possible to confine the more extensive field programmes to those minimum size questions likely to give valid answers.

For example, using a logical process on the data presented in Table 4 to anticipate the effect of increasing the minimum size from 4½ to 5 inches in the Norfolk fishery, since y=18.8, an increase in weight yield exceeding 15% could not occur if $\bar{W}_R/\bar{W}_1$ was less than 1.35 (Table 3). The value of $\bar{W}_R/\bar{W}_1$ was, in fact, 1.69, in which case a gain of 15% or more could occur with values of $x \leq 20$ (Table 3). From Table 2, since $\dot{N}_R=57.1$, values of $x \leq 20$ occur when $E.\exp(-Mt') \geq 0.65$. The range of circumstances in which values of $E.\exp(-Mt')$ could be ≥ 0.65 (Table 1) suggests that a more detailed examination of this fishery would be likely to lead to useful results.

By contrast, in considering a minimum size increase from 4½ to 5 inches in the Whitby, Yorkshire, fishery, based on 1962 data (Table 5c), since y=12.0 and $\bar{W}_R/\bar{W}_1=1.21$, Table 3 makes it clear that a gain in weight of even 5% is unlikely ever to be achieved. In the Bridlington/Grimsby area, however, where y=18.2 and $\bar{W}_R/\bar{W}_1=1.50$ (Table 5a), a gain in weight of 15% would be possible when $x \leq 11$ (Table 3), which, since $\dot{N}_R=27.4$, could occur at values of $E.\exp(-Mt') \geq 0.60$ (Table 2). At low values of $M(\leq 20\%)$ the value of $E.\exp(-Mt')$ exceeds 0.60 over a wide range of F (Table 1), so that this would clearly be an area worthy of further study. The yield from the Whitby area, on the other hand, would be unlikely to benefit from a change in minimum size and a detailed study for that purpose could not be expected to be profitable.

In the following sections, the method described has been applied in more detail to the assessment of changes in yield associated with possible minimum size increases in the edible crab fishery of Yorkshire.

Yield Assessment in the Yorkshire Fishery

For practical purposes, the area covered by the Yorkshire crab fishery has been subdivided into three sub-areas whose major ports are Bridlington, Scarborough and Whitby, respectively. The data required for yield assessment were presented by Edwards (1967 and in prep.), from which values for the required parameters have been selected.

The information needed for steps 1–7 in Table 4 (for Norfolk) were obtained in a similar manner for Yorkshire, using the number, size and weight composition of the annual catch. The procedure for obtaining the relative numbers and weights of crabs in the various size ranges, i.e. carapace width 4½ to 4¾ inches (114 to 121 mm inclusive) and so on, was briefly as follows. Samples from catches were measured at sea on commercial boats and at the main ports, Bridlington, Scarborough and Whitby, recording males and females separately. The total catch for each port in Yorkshire is recorded weekly, by MAFF collectors, as weight landed in stones (1 stone=6.35 kg). Length/weight relationships, obtained by weighing samples of crabs at a representative port (Whitby), were fitted to the sample data by linear regression of logarithms (Hancock and Edwards, 1966). These could be used to convert monthly catches from weight to nu and, taking the proportions in the samples, the fracti the samples, in numbers and weight, represented be the selected minimum sizes were used to calculate th portions N_R and N_K (Figure 1) on a monthly basi finally as totals for each fishing season. The mean w $\bar{W}_1$, $\bar{W}_R$ and $\bar{W}_K$ (Figure 1) could then be calculated same way as for Norfolk.

Values for t′ of 1 for females and 1.2 for males appropriate also for Yorkshire (Hancock and Edw 1967; Edwards, 1966). The method of estimating tota tality coefficients (Z) from size composition data, us Hancock (1965, p. 87), seems inapplicable here in view observed migration of at least large females from the ern to the northern part of the fishery, and sometimes the fishery altogether (Edwards, 1967). This will affe size composition considerably, thus rendering invali assumptions made in the estimation. It has therefore necessary to restrict the present assessment to likely of F (from tagging experiments) and to examine the eff the result, of substituting different values of M.

The results of tagging experiments (Edwards, showed the rate of exploitation to be approximately By Ricker's (1958) definition, the rate of exploi $=F\left[1-\exp\left\{-(F+M)\,t\right\}\right]/(F+M)$ with $t=\frac{1}{2}$ year f duration of the fishery, and substituting likely values values of F, the instantaneous fishing mortality coeff could be calculated. There is no evidence for a high r natural mortality in east coast crab fisheries, and the stitution of M=0.11 (or 10% per year in the abser fishing) gives a value of F of about 0.8. Reference to T shows that for F=0.72 and M=0.11, the resultant a losses would be 29 and 8% respectively. Similarly F=0.72 and M=0.22, the annual mortalities gene would be 28 and 16% respectively.

The main assessment has been based on F=0.7 M=0.11. If natural mortality is greater than that repr ed, the magnitude of loss in numbers and gain in weigh have been overestimated. Additional calculations have made, substituting different values of F and M to cal the quotient $E.\exp(-Mt')$ (Table 1). For F=0.72 M=0.11, and using t′=1 for females and 1.2 for male resulting values of $E.\exp(-Mt')$ are 0.71 and 0.70 re ively. For calculations involving total catch, i.e. unsepa into two sexes, the value 0.71 will be used.

esults of
ıe Assessment

ıe results of using values of F=0.72 (fishing mortality
ng 6 months=approx. 30%), M=0.11 (natural mortal-
=10% per year) and E.exp(−Mt′)=0.71 for females and
l crabs and 0.70 for males (i.e. t′=1, or annual moulting
emales and total crabs, and 1.2 for males) for data from
Yorkshire fishery during 1962 have been given as an
mple in Tables 5(a–d). The results for the three years
2 to 1964 have been summarized in Table 6a and these
ıonstrate clearly that any percentage gains in weight in
steady state which would have resulted from an increase
inimum size to 4¾ inches were likely to be very small.
s is partly because the proportion in numbers of the
ent size composition between 4½ and 4¾ inches was
ll, representing 13, 14 and 9% in 1962, 1963 and 1964,
ectively. The equivalent figure for Norfolk was about
% (Table 4) where the gain in weight, even with M=0.22,
expected to be 16%. The greatest gain from an increase
¾ inches would occur at Bridlington (9% in 1962), where
gher proportion of the smaller crabs is generally found
ı on grounds farther north.

Considering an increase in minimum size from 4½ to 5 inches, the predicted gains in weight would be somewhat larger, but even so the maximum gain for any port during the three years would have been 15%, at Bridlington in 1962. Once again, the highest gain would have occurred each year at Bridlington, the gain lessening progressively northwards, the three-year averages for Bridlington, Scarborough and Whitby being 12, 8 and 5% respectively, with an average of 8% for the whole fishery served by the three ports. There would have been no substantial difference between gains from males and females

An increase in the minimum size by an additional half-inch to 5½ inches would by no means have doubled the gain to be obtained from the increase by the first half-inch from 4½ to 5 inches. At 5½ inches about half the numbers in the catch would have to be rejected during the first year after changing the minimum size. For an increase to 5 inches, the numbers which would have needed to be rejected during the year after changing the minimum size would have amounted to 27, 27 and 21% during the years 1962–4 respectively. The number and weight of crabs lost immediately to the fishery as a result of changing the minimum size would clearly be an important consideration when contemplating such a change. It was concluded that in the year of greatest weight gain, i.e. 15% per annum at Bridlington (1962), the annual loss for a year or more would have been 26% in weight and 38% in numbers (Table 5a). The annual loss in numbers in the steady state would have been 11%.

BLE 5 *Assessment of the changes in yield of the Yorkshire fishery which would result from minimum size increases from 4½ inches to 4¾, 5 and 5½ inches, using data from Edwards (in prep.) for* 1962. *Symbols as in first column of Table* 4

	Loss at 4¾″			Loss at 5″			Loss at 5½″		
	Female	Male	Total	Female	Male	Total	Female	Male	Total
Bridlington and Grimsby									
	322 974	386 013	708 987	322 974	386 013	708 987	322 974	386 013	708 987
	68 414	72 288	140 702	133 436	138 672	272 108	244 963	248 449	493 412
	21.2	18.7	19.8	41.3	35.9	38.4	75.8	64.4	69.6
	19 225	28 517	47 742	19 225	28 517	47 742	19 225	28 517	47 742
	2 781	3 176	5 957	5 829	6 612	12 441	12 234	13 803	26 037
	14.5	11.1	12.5	30.3	23.2	26.1	63.6	48.4	54.4
	0.0595	0.0739	0.0673	0.0595	0.0739	0.0673	0.0595	0.0739	0.0673
	0.0646	0.0808	0.0735	0.0707	0.0886	0.0808	0.0896	0.1070	0.1007
	0.0896	0.1070	0.1007	0.0896	0.1070	0.1007	0.0896	0.1070	0.1007
	33.1	28.8	32.4	18.6	16.0	18.2	0	0	0
$\bar{W}_1$	1.51	1.45	1.50	1.51	1.45	1.50	1.51	1.45	1.50
	1	1.2	1	1	1.2	1	1	1.2	1
$e^{-Mt'}$	0.71	0.70	0.71	0.71	0.70	0.71	0.71	0 .70	0.71
	6.1	5.7	5.8	11.9	10.8	11.0	22.0	19.2	20.3
$(1-x)(\bar{W}_R/\bar{W}_1)-100$	41.9	36.3	41.0	32.9	29.1	33.5	17.8	17.5	20.0
ain	9	8	9	14	13	15	18	18	20

5b *Scarborough, Filey and Flamborough*

	Loss at $4\frac{3}{4}''$			Loss at $5''$			Loss at $5\frac{3}{4}''$		
	Female	Male	Total	Female	Male	Total	Female	Male	Tota
C_1	239 998	236 190	476 188	239 998	236 190	476 188	239 998	236 190	476
N_R	25 729	30 448	56 177	58 063	67 687	125 750	118 765	128 797	247
$\dot{N}_R$	10.7	12.9	11.8	24.2	28.7	26.4	49.5	54.5	52.0
Y_1	18 044	19 155	37 199	18 044	19 155	37 199	18 044	19 155	37 1
loss	1 053	1 351	2 404	2 560	3 294	5 854	6 131	7 217	13 3
%	5.8	7.1	6.5	14.2	17.2	15.7	34.0	37.7	35.9
$\bar{W}_1$	0.0752	0.0811	0.0781	0.0752	0.0811	0.0781	0.0752	0.0811	0.07
$\bar{W}_K$	0.0793	0.0865	0.0828	0.0851	0.0941	0.0894	0.0983	0.0112	0.10
$\bar{W}_R$	0.0983	0.1112	0.1043	0.0983	0.1112	0.1043	0.0983	0.1112	0.10
y	22.6	26.5	24.3	13.3	15.0	14.0	0	0	0
$\bar{W}_R/\bar{W}_1$	1.31	1.37	1.34	1.31	1.37	1.34	1.31	1.37	1.3
t'	1	1.2	1	1	1.2	1	1	1.2	1
E.exp(−Mt′)	0.71	0.70	0.71	0.71	0.70	0.71	0.71	0.70	0.7
x	3.2	3.9	3.5	7.0	8.7	7.5	14.5	16.5	15.1
$(100-x)(\bar{W}_R/\bar{W}_1)-100$	27.1	31.5	28.6	21.8	24.7	23.3	11.4	13.7	13.9
% gain	5	5	4	9	10	9	11	14	14

5c *Whitby and Staithes*

	Loss at $4\frac{3}{4}''$			Loss at $5''$			Loss at $5\frac{3}{4}''$		
	Female	Male	Total	Female	Male	Total	Female	Male	Tota
C_1	397 767	242 275	640 042	397 767	242 275	640 042	397 767	242 275	640 0
N_R	13 651	26 770	40 421	33 446	54 121	87 567	93 597	127 657	221
$\dot{N}_R$	3.4	11.0	6.3	8.4	22.3	13.7	23.5	52.7	34.6
Y_1	36 490	20 193	56 683	36 490	20 193	56 683	36 490	20 193	56 68
loss	558	1 186	1 744	1 487	2 819	4 305	4 462	7 384	11 84
%	1.5	5.9	3.1	4.1	14.0	7.6	12.2	36.6	20.9
$\bar{W}_1$	0.0917	0.0833	0.0886	0.0917	0.0833	0.0886	0.0917	0.0833	0.088
$\bar{W}_K$	0.0935	0.0882	0.0916	0.0961	0.0923	0.0948	0.1053	0.1118	0.10
$\bar{W}_R$	0.1053	0.1118	0.1071	0.1053	0.1118	0.1071	0.1053	0.1118	0.10
y	12.4	25.2	16.4	9.2	18.2	12.0	0	0	0
$\bar{W}_R/\bar{W}_1$	1.15	1.34	1.21	1.15	1.34	1.21	1.15	1.34	1.2
t'	1	1.2	1	1	1.2	1	1	1.2	1
E.exp(−Mt′)	0.71	0.70	0.71	0.71	0.70	0.71	0.71	0.70	0.7
x	0.9	3.3	1.7	2.3	6.6	4.1	7.0	15.9	10.2
$(100-x)(\bar{W}_R/\bar{W}_1)-100$	13.9	30.0	18.6	12.7	24.6	16.2	7.0	12.6	8.9
% gain	2	5	2	4	6	4	7	13	9

	Loss at 4¾″			Loss at 5″			Loss at 5¼″		
	Female	Male	Total	Female	Male	Total	Female	Male	Total
5d *Whole Yorkshire fishery*									
	960 739	864 478	1 825 217	960 739	864 478	1 825 217	960 739	864 478	1 825 217
	107 794	129 506	237 300	224 945	260 480	485 425	457 325	504 903	962 228
	11.2	15.0	13.0	23.4	30.1	26.6	47.6	58.4	52.7
	73 759	67 865	141 624	73 759	67 865	141 624	73 759	67 865	141 624
	4 392	5 713	10 105	9 876	12 725	22 601	22 827	28 404	51 231
	6.0	8.4	7.1	13.4	18.8	16.0	30.9	41.9	36.2
	0.0768	0.0785	0.0776	0.0768	0.0785	0.0776	0.0768	0.0785	0.0776
	0.0813	0.0846	0.0828	0.0868	0.0913	0.0888	0.1012	0.1097	0.1047
	0.1012	0.1097	0.1047	0.1012	0.1097	0.1047	0.1012	0.1097	0.1047
	23.0	27.2	24.6	14.4	16.4	15.0	0	0	0
$\bar{W}_1$	1.32	1.40	1.35	1.32	1.40	1.35	1.32	1.40	1.35
	1	1.2	1	1	1.2	1	1	1.2	1
$p(-Mt')$	0.71	0.70	0.71	0.71	0.70	0.71	0.71	0.70	0.71
	3.2	4.5	3.8	6.7	9.0	7.8	13.9	17.4	15.4
$-x)(\bar{W}_R/\bar{W}_1)-100$	28.0	33.0	29.6	22.8	27.4	24.2	13.5	16.2	14.8
ain	5	6	5	8	11	9	14	16	15

eliability of arameters Used n the Assessment

his may best be examined by considering the assumps implicit in the use of the expression for the yield assessnt (p. 1).

Figures for numbers and weight landed have been based data from each area for each year under assessment. The gth/weight relationship and the size composition have o been examined separately each year. The parameters , $\bar{W}_1$, $\bar{W}_R$ and $\bar{W}_K$ have therefore been calculated indedently for each year and, subject to the usual limitations sampling procedures, need not therefore be considered as iables in an assessment confined to any year.

The value of t′ is based on an average estimate of moult quency. The value of t′=1 for females seems likely to be rect over the range 4½–5 inches, but the moult frequency nales appears to decline rapidly over this range (Edwards, 6), and a value higher than 1.2 might well be appropriate, ing also a higher value than the t′=1 used for total crabs. as been shown, however, that even quite large values of o not markedly affect the result of the present assessment; example, using t′=1.50, which represents only 50% ulting in the first year and most of the remainder in the ond year (Hancock, 1965), instead of t′=1.0, the 1962 dlington result for total crabs (Table 6b) would only be uced from 15% to 14% gain from an increase to 5 inches. e also Table 7).

3. The assessment used a value for moult increment of about 1 inch, which determines the value of $\bar{W}_R$. The evidence so far suggests that this value is unlikely to change markedly from year to year, or even from place to place on the Yorkshire coast.

4. The computation of the value of E for Yorkshire requires a knowledge of F and M and makes the assumption that the fishery is pursued for only 6 summer months. The latter is substantially true, though at Whitby there is a limited fishery during the winter. However, since this is based mainly on large crabs, it seems unlikely to be affected by the minimum size changes being considered here.

Natural mortality (M) cannot be estimated separately by any known method, and indirect estimation from total mortality has been found to be invalid for the Yorkshire fishery. The value of 10% natural mortality used is quite low, and the effects of higher values of the natural mortality coefficient have also been considered (Table 7), and would have a marked reducing effect on the percentage gains so far obtained.

Fishing mortality (F) has been calculated on the basis of a rate of exploitation of approximately 30%. This value was obtained from an experiment confined to the Bridlington–Grimsby area in 1964, and was considered (Edwards, 1967) to be the most reliable result of three years of tagging (1962–64). From the results of these, in 1962 the rate of exploitation obtained for Bridlington was lower than for Scarborough or Whitby, but at Bridlington, the tagged crabs had been liberated farther offshore, and the rate of exploitation would have shown a greater tendency to underestimation than at Whitby. In 1963, tagged crabs were liberated close inshore over all three areas, where the rates

of exploitation were similar at about 60%, though it was considered that they were all over-estimated by this technique of liberation. The 1964 value of 30% obtained for Bridlington was approximately halfway between the 14% in 1962 (underestimated) and 61% in 1963 (overestimated), also for Bridlington. It seems likely, particularly in view of the much lowered effort at Whitby in 1964, that the rate of exploitation there was no more than at Bridlington. Table 7 shows the effect on the result of using a large value of F, i.e. 2.40, representing nearly 70% loss due to fishing during 6 months, again with M=0.11 for the whole fishery in 1963, and indicates that the % gain would have been increased from 9% to 14%; if F were 2.40 and M=0.22 this gain would have remained unchanged at 9%.

5. The calculation makes the assumption that the p tion is a discrete one. The effect of annual inshore tions has already been considered when computing th of exploitation from the results of tagging. It is clea there are migrations into the Yorkshire fishery, mainly farther south, and it seems likely that these crabs wil been included in the pre-moult estimates of the stock effect of immigration would be to cause the rate of exp tion to be underestimated (Hancock, 1965, p. 85), larger value of F has been considered in the previous graph. The migration of crabs out of the fishery foll moulting is not known quantitatively, but it would ha effect of reducing any predicted gains.

TABLE 6 *Percentage increase in weight in the steady state, and the percentage loss in weight in the first year after an in in the minimum size*

Port	1962		1963		1964		Mean	
	% gain	loss in first year	% gain	loss in first year	% gain	loss in first year	% gain	loss in first year
(a) from $4\frac{1}{2}$ to $4\frac{3}{4}$ inches								
Whitby	2	3	5	5	1	2	3	3
Scarborough	4	7	4	6	3	4	4	6
Bridlington	9	13	7	13	6	6	7	11
Whole area	5	7	6	8	4	4	5	6
b) from $4\frac{1}{2}$ to 5 inches								
Whitby	4	8	6	10	4	7	5	8
Scarborough	9	16	8	12	7	11	8	13
Bridlington	15	26	11	26	9	17	12	23
Whole area	9	16	9	17	7	12	8	15

TABLE 7 *Effects of varying the parameters on the predicted changes in weight which would result from an increase in min size from $4\frac{1}{2}$ to 5 inches in the whole Yorkshire fishery (based on 1963 data)*

F	0.72	0.72	2.40	2.40
M	0.11	0.11	0.11	0.11
t′	1.5	1	1	1.5
	7%	9%	14%	13%
	M increasing ↓	M increasing ↓	M increasing ↓	M increasing ↓
	1%	2%	9%	6%
t′	1.5	1	1	1.5
M	0.22	0.22	0.22	0.22
F	0.72	0.72	2.40	2.40

t′ increasing ← (7% → 9%) F increasing → (14% → 13%) t′ increasing →

t′ increasing ← (1% → 2%) F increasing → (9% → 6%) t′ increasing →

ummary
nd Conclusions

or the Yorkshire fishery as a whole, the immediate loss umbers resulting from a minimum size increase of 4½ to ches would be about 25%, and the loss in weight about ,, during the first year after making the change. The ry would be expected to take at least two years to settle n to the steady state.

Even considering a low rate of natural mortality of 10% annum, the overall gain to the Yorkshire fishery would nlikely to exceed about 8% in weight. The annual loss umbers in the steady state would be expected to be about

f natural mortality was greater than 10%, the percentage would be negligible. If the rate of exploitation had been erestimated the gain would still be unlikely to exceed %, but this figure would again be reduced if the natural tality was also more.

The greatest gains in weight of up to 15% per annum e predicted for Bridlington, subject to the provisos in agraph 3 above, but there the immediate loss in numbers ld be nearly 40% and the weight loss 26%.

n view of the uncertainty of some of the parameters d, coupled with the small size of predicted increases, even er conditions favouring an improved yield, an increase he minimum size could not at that time (1966) be con- red as a sound measure for improving the yield of the kshire fishery. This conclusion seemed particularly valid inst the background of decreasing effort, and a change he minimum size was not in fact recommended.

The possibility of changing the minimum size over part he fishery was also considered. Bridlington would be the ious choice, in view of the magnitude of predicted gains. wever, the likelihood of at least some of the protected os being lost from this fishery by migration farther north, ere the effort is smaller, reduces any chance of benefit to fishery as a whole. This is apart from the difficulties of inistering separate minimum sizes for such closely re- d and even overlapping fisheries.

References

EDWARDS, E. ,1965. Observations on growth of the edible crab (*Cancer pagurus*). Rapp. P.-v. Réun. *Cons. int. Explor. Mer*, **156,** 62–70.

EDWARDS, E., 1966. Further observations on the annual growth of the edible crab (*Cancer pagurus*) along the east coast of England. *ICES C.M.* 1966. *Shellfish C'tee Doc. No. M:*17 (mimeo).

EDWARDS, E., 1967. Yorkshire crab stocks. *MAFF Laboratory Leaflet* (*new series*) *No.* 17, 34 pp., Fish Lab., Burnham-on-Crouch.

EDWARDS, E., 197?. The Yorkshire fishery for edible crabs (*Cancer pagurus*). *Fishery Invest., Lond.* (In prep.).

GULLAND, J. A., 1961. The estimation of the effect on catches of changes in gear selectivity. *J. Cons. int. Explor. Mer*, **26,** 204–14.

HANCOCK, D. A., 1965. Yield assessment in the Norfolk fishery for crabs (*Cancer pagurus*). Rapp. P.-v. Réun. *Cons. int. Explor. Mer*, **156,** 81–93.

HANCOCK, D. A. and EDWARDS, E., 1966. The length/weight relationship in the edible crab (*Cancer pagurus*). *ICES, C.M.* 1966, *Shellfish C'tee, Doc. No. M:*18 (mimeo).

HANCOCK, D. A. and EDWARDS, E., 1967. Estimation of annual growth in the edible crab (*Cancer pagurus* L.). *J. Cons. int. Explor. Mer*, **31,** 246–64.

RICKER, W. E., 1958. Handbook of computations for biological statistics of fish populations. *Bull. Fish. Res. Bd Can., No.* 119, 300 pp.

Printed in England for Her Majesty's Stationery Office by W. A. SMITH (Leeds) Ltd.
Dd 506716 K8 7/75